Venison: Meat from red deer (*Cervus elaphus*) and reindeer (*Rangifer tarandus tarandus*)

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Implications

- Venison (deer meat) attracts a premium price relative to meats from other species due to its image among consumers as a safe, nutritious, palatable, and natural product. The red deer and reindeer industries must protect this image and the unique qualities of venison in their farming and processing practices. Thus, focus on consumer demands in both domestic and export markets is essential.
- The slaughter, boning, and processing of carcasses from farmed red deer in New Zealand and semi-domestic reindeer in Fennoscandia (Norway, Sweden, and Finland) are performed at facilities specifically designed for deer but include the technologies developed for the commercial processing of other species of meat animals.
- There are inherent differences between venison and other red meats in terms of its rate of tenderization and loss of red color; thus, species-specific tailoring of process inputs are required by the meat industries to optimize the overall quality of these meats.

Key words: carcass quality, color, meat pH, nutritional composition, tenderness, water-holding capacity

Figure 1. Farmed red deer (*Cervus elaphus*) is the main source for venison production in New Zealand (source: J. Solheim).

Introduction

To illustrate the most important sources of venison (deer meat) in the world, the examples in this article are taken from the deer farming industry in New Zealand and the traditional reindeer husbandry cultures in Fennoscandia (Sweden, Norway, and Finland) and Alaska (with roots in Russia and Fennoscandia). These deer industries are mainly focused around pasture-based venison production systems. The red deer (*Cervus elaphus*) is the most common deer species for venison production in New Zealand (Figure 1) while the reindeer (*Rangifer tarandus tarandus*) dominate venison production in Fennoscandia and Alaska (Figure 2). Reindeer husbandry is performed in a less-intensive way than red deer farming, with the reindeer free ranging (not enclosed in fenced areas) in forests and on the mountain tundra. Both reindeer in Fennoscandia and red deer in New Zealand are occasionally fed supplements or replacements, particularly during winter when pastures cannot provide enough nutrition for maintenance and growth (Staaland and Sletten, 1991; Wiklund et al., 2008a).

Consumer opinion is increasingly important to meat industries worldwide, and consumers value the attributes such as flavor, tenderness, and nutrient content when evaluating the quality of meat (Dransfield, 2003). In addition, consumers judged meat production systems where the animals graze in a free-range manner to be more animal friendly and ethical compared with the standard commercial production of beef, pork, or poultry (for an overview, see Hoffman and Wiklund, 2006). Therefore, venison with its low fat content, favorable fat composition, and increased mineral content is a product that meets most of the criteria (e.g., nutritional composition and ethical quality) demanded by the discerning meat consumers of today (Hoffman and Wiklund, 2006). In Table 1, the nutritional composition of red deer and reindeer venison, beef, and lamb is compared.

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Deer Production and Statistics

Fennoscandia

The Sami people inhabiting the region between Tromsø in northern Norway and the Kola Peninsula in northwest Russia have been reindeer herders for thousands of years. Traditionally, the reindeer were managed in an intensive manner where the herders tended their herds all year around. During the 20th century, reindeer herding has gradually become more and more extensive. Sami families are not nomadic but live in communities and use all kinds of modern technology for reindeer herding, such as helicopters, airplanes, motorbikes, and snowmobiles (Bäck, 1993). However, the traditional knowledge around reindeer is still very much alive in the everyday life of Sami reindeer herders.

Figure 2. Semi-domestic reindeer (*Rangifer tarandus tarandus*) is the traditional venison producer for reindeer herders, the Sami people, in Fennoscandia (Norway, Sweden, Finland, and Russia), but also for Alaskan natives, the Inupiat (source: A. Wiklund).

Historically, reindeer were slaughtered at the selection site, (i.e., at various locations in the forests or mountain tundra surrounding the reindeer-herding districts of the Sami people). At these selection sites, permanent corrals for handling and sorting of animals were available along with some type of basic slaughter facilities. New directives regarding reindeer meat inspection were introduced in the 1990s (e.g., by the Swedish National Food Agency, 1993). Consequently, many of the former outdoor slaughter sites were closed, the numbers of reindeer transported to slaughter increased, and new mobile slaughter facilities were developed. Today, the rules applied for animal transport, veterinary inspection of living animals and carcasses, stunning methods, slaughter hygiene, carcass grading, and chilling conditions for reindeer are similar to those applied for other domestic species. Most of the specialized reindeer slaughter plants are approved to EU standards for other meat species.

The number of reindeer (winter stock; the number of animals after the annual slaughter) in Fennoscandia is approximately 700,000 [Sweden: 248,296 (Sami Parliament Sweden, 2014); Finland: 203,700 (Muuttoranta, 2014); Norway: 246,800 (Reindriftsforvaltningen, 2013)] and varies according to changes in weather conditions, availability of pastures, and predation. Meat is the main product for the reindeer industry, and to maximize meat production, it is crucial to align the numbers of reindeer to the available grazing resources. Herd composition and slaughter strategies are also important tools to influence meat production (Holand, 2007). The greatest possible proportion of reproductive females combined with a slaughter scheme based on calves is a common approach used in the Fennoscandian countries. The proportion of slaughtered calves per total number of slaughtered reindeer today exceeds 70% (Muuttoranta, 2014; Sami Parliament Sweden, 2014). About 2,000 to 3,000 tons of reindeer meat are produced annually in Finland (Muuttoranta, 2014), 1,900 tons in Norway (Reindriftsforvaltningen, 2013), and Swedish statistics demonstrate a production of 1,200 tons in 2013 (Sami Parliament Sweden, 2014). Due to the small production volumes, reindeer meat is a very exclusive gourmet product, which is in high demand and often on the menu of high-end restaurants. Almost no reindeer meat is exported from Fennoscandia. The meat is consumed fresh but is also marketed as cold- or hot-smoked and dried meat products (Figure 3).

Table 1. Examples of the nutritional composition of red deer and reindeer venison, beef, and lamb. All analyses are from the Food Database of the Swedish National Food Agency (2014).

Species	Muscle/meat cut	Protein, n	Fat, g	Iron,	Selenium, m	Vitamin E,	Cholesterol,	Total PUFA,*
		g/100 g	g/100	mg/100g	µg/100g	mg/100g	mg/100g	g/100g
Red deer	*M. longissimus* (striploin)	22.6	1.2	3.3	9.0	0.8	59.0	0.3
Reindeer	*M. semimembranosus* (inside)	22.6	1.8	3.4	19.7	0.8	69.1	0.4
Beef	*M. longissimus* (striploin)	21.8	3.9	2.2	9.0	0.1	52.0	0.2
Lamb	*M. longissimus* (striploin)	20.0	2.5	1.6	1.4	0.7	78.0	0.2

*Polyunsaturated fatty acids.

Alaska

Domestic reindeer were introduced to Alaska from Siberia, Russia in 1892 to establish a predictable meat source and economic development for Alaskan Natives (Stern et al., 1980). Most of the imported animals were Chukchi stock, but reindeer from the Tungus of eastern Siberia were also purchased. At first, Chukchi herders were employed to train the Inupiat in handling and herding, but cultural differences created friction between the two groups. The Chukchi herders returned to Siberia and Sami herders from Norway and Finland were brought to the Seward Peninsula to teach reindeer husbandry to the Inupiat.

The introduced reindeer did well, and more than 500,000 reindeer could be found in Alaska spread from Barrow to the Aleutian Islands during the 1920s (Stern et al., 1980). The numbers of reindeer on the Seward Peninsula decreased drastically from 127,000 in 1927 to 25,000 in 1950 largely from the influence of World War II where the cessation of close herding, overgrazing brought about by the open-grazing method, predation, and the presence of caribou led to large reindeer losses (Stern et al., 1980). After a revitalization program initiated by the Bureau of Indian Affairs in 1941 to improve reindeer management, 17 new herds under private management were started on the Seward Peninsula. To be granted a grazing permit on government lands, the herder must develop a grazing management plan in cooperation with the Natural Resources Conservation Service (NRCS, 1953, 1954). In 1971, the Reindeer Herder's Association was formed to unite the herders into a political organization to work with government agencies and to advocate efforts to further develop the reindeer industry (Bader and Finstad, 2001).

Since the 1970s, reindeer herding has been a significant economic factor in villages on the Seward Peninsula (Schneider et al., 2005). Sales of velvet antler and meat generated more than $1 million in annual revenue for the rural communities of the Seward Peninsula during the early to mid-1990s (Carlson, 2005). Most herders believe that meat sales provide the economic backbone for the industry and manage their herds accordingly. All present-day herders castrate excess males to reach a ratio of one male for every 15 to 20 females in their herds. Although velvet antler sales generated US$10.3 million and reindeer meat sales generated US$9.6 million from 1987 to 2003 (Alaska Agriculture Statistics, 1987–2003), herders believe development of the meat industry is key to their long-term economic success (Finstad et al., 2006).

Ground meat and steaks are preferred by USA consumers. Thus, a slaughtered animal must be of sufficient size to produce a cut of meat that is large enough to satisfy typical American expectations of a pan-fried or grilled steak. Hence, the Alaska reindeer industry must rely on a larger-framed animal with fully developed muscle groups rather than calves as in the Fennoscandian reindeer industry. Therefore, more work needs to be done on the relationship between pastures and supplemental feeding on the growth of reindeer and the development of slaughtering and processing methods to produce a uniform cut of meat that will satisfy the American public.

New Zealand

New Zealand has pioneered the development of farm-based production systems for venison. However, deer are not native to New Zealand. The first deer were brought there from England and Scotland for sport (hunting) in the mid-late 19th century. In the early 1970s, industry pioneers started capturing live deer from the wild and farming them to produce venison for well-established markets in Europe. A new industry was born and rapidly spread throughout New Zealand (Deer Industry New Zealand, 2014). Scientific knowledge, expertise, and genetics from Europe and North America were used to develop farmed animals, and markets grew profitably along with the usual growing pains, particularly in the early part of the new millennium. Since 2006, prices and markets have been relatively stable, and the deer industry has acted in a well-coordinated way, industry marketing campaigns have had a positive impact, and marketers have cultivated new customers, and therefore, demand (Deer Industry New Zealand, 2014). There are currently about 2,800 deer farms in the country, ranging in size from smaller lifestyle properties to farms carrying many thousands of deer. On these farms, there are approximately 1.1 million deer (Deer Industry New Zealand, 2014).

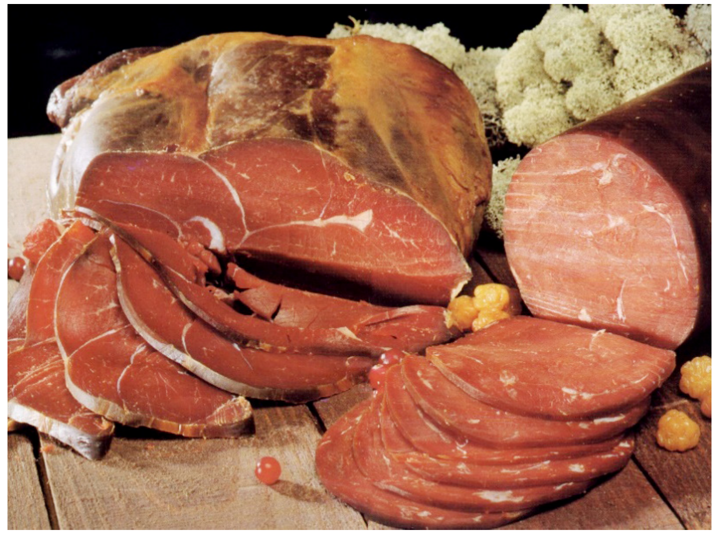

Figure 3. Reindeer venison is a delicacy. Cold- or hot-smoked and dried meats are examples of the most valued processed products (source: Association of Reindeer Herding Cooperatives, Rovaniemi, Finland).

An important component of the research and development for the New Zealand deer industry has been to define systems for optimal production, nutrition, and growth of deer, together with post-mortem processing systems to guarantee venison of high quality. The deer industry meets the seasonal market demand for venison by slaughtering deer in early spring, when animals are 9 to 11 months old (Wiklund et al., 2008a), although year-round supply of venison to high-value European markets is a strategy that the industry is seriously considering in the near future.

For specialty culinary products, deer are slaughtered and venison processed in designated facilities licensed by the New Zealand Ministry for Primary Industries. The amount of venison exported from New Zealand in 2011 was estimated at 14,850 tons (Deer Industry New Zealand, 2014). An animal welfare Code of Practice governs the humane treatment of deer before processing to ensure minimum stress and to enhance product quality. Venison is further processed according to customer requirements. The trend is towards value-added (or further processed) cuts, where the bones and "silverskin" (the connective tissue surrounding the muscles) are removed (Figure 4).

Carcass and Meat Quality

Consumers and processors associate certain attributes like safety, tenderness, water-holding capacity, color, and flavor with the eating and processing quality of meat. Most of the basic principles (effects of gender, age, and region) and practices (nutrition, pre-slaughter handling, trans-

Figure 4. The New Zealand Deer Industry has developed appropriate protocols for venison processing, hygiene, handling, packaging, and storage (source: Y. Li).

port, lairage, stunning, and electrical stimulation) that influence meat quality and composition that are applicable to more traditional red meat species are also applicable to deer and venison (Hoffman and Wiklund, 2006). Deer and reindeer represent meat-producing species that exist both as wild and domestic (farmed) animals. Fennoscandia (Sweden, Norway, and Finland), and New Zealand lead the world in commercial venison production from semi-domestic or farmed deer species, reindeer, and red deer, respectively. The slaughter, boning, and processing of carcasses from these animals are performed at facilities specifically designed for deer but include the technology developed for the commercial processing of other species of meat animals (Wiklund and Smulders, 2011).

Meat pH

Meat pH values of 5.5 to 5.7 measured approximately 24 hours post slaughter (so called ultimate pH) are within the normal range, while values over 5.8 result in reduced shelf life, especially for vacuum-packaged meat (Gill, 2004). Meat with very high pH [>6.2; so called DFD (dark, firm, dry)] meat is a persistent quality defect found in mammalian meat species (Gill and Newton, 1981). Two comprehensive surveys of red deer (n = 3500; New Zealand) and reindeer (n = 3400; Sweden) demonstrated meat pH values of 5.8 and greater for 11% (red deer) and 29% (reindeer) of the measured carcasses, which would have an obvious risk of reduced shelf life (Wiklund et al., 1995; Pollard et al., 1999).

Hygienic quality

Shelf life of fresh meat is often determined by microbiological growth, (e.g., the total amount and types of microorganisms present on the meat). A critical limit often used to judge microbiological/hygienic quality of meat is 7 $\log_{10}$ CFU (colony forming units)/g of aerobic microorganisms. Values of 7 $\log_{10}$ CFU/g and above indicate that the meat is not fit for human consumption (Wiklund et al., 2010b). Factors of importance for the microbial growth on chilled meat are pH, slaughter hygiene, and chilling conditions/temperatures.

Reindeer meat has traditionally been sold as a frozen product in Fennoscandia and Alaska; however, the demand for fresh chilled meat is slowly increasing. There is very limited knowledge available about the properties of chilled reindeer meat in relation to handling, packaging, and storage. On the contrary, New Zealand has extensive experience in marketing venison as fresh chilled meat to Europe and the USA. The New Zealand Deer Industry together with the venison processing companies have developed good protocols for processing, hygiene, handling, packaging, and storage (Wiklund et al., 2010b). Microbiological data reported for New Zealand venison demonstrated values of 2 $\log_{10}$ CFU/g and 4 $\log_{10}$ CFU/g for venison stored at -1.5°C for 3 and 9 weeks, respectively (Wiklund et al., 2010b). The low storage temperature combined with good hygienic quality of the meat make it possible for the New Zealand venison industry to guarantee a long shelf life (up to 12 to 14 weeks) for these chilled venison cuts. In contrast, Swedish reindeer meat had much poorer hygienic quality and shelf life; microbiological data of 6.8 $\log_{10}$ CFU/g for reindeer meat stored 3 weeks at +4°C have been reported (Wiklund, 2011). Increased demand and handling of vacuum-packed fresh, chilled venison will immediately highlight any problems with pH values that are currently "invisible" in the frozen products. As for other sectors in the meat industry, the quality and shelf life of the fresh, chilled meat has to be guaranteed. Routine pH measurements of all deer/reindeer carcasses intended for production of vacuum-packaged fresh, chilled meat would contribute to optimizing venison quality and shelf life (Figure 5).

Figure 5. Meat pH measured 24 hours after slaughter is a predictor of meat quality. A value of 5.5 to 5.7 is within the normal range (source: B. Åhman).

Tenderness

Venison is more tender than beef, and for some deer species like reindeer and fallow deer (*Dama dama*), aging of the meat beyond 1 to 3 days post slaughter is not necessary (Barnier et al., 1999; Sims et al., 2004). A number

Figure 6. The majority of reindeer in Alaska are slaughtered through a state-regulated field slaughter system. The meat can be marketed locally provided animals are slaughtered on snow when ambient temperature is below 0°C (source: E. Wiklund).

of studies showed that meat from red deer, fallow deer, and reindeer was more tender compared with beef aged for the same period of time (Rincker et al., 2006; Farouk et al., 2009; Hutchison et al., 2012, 2014). The phenomenon of fast tenderization in venison has been explained by the increased activity of proteolytic enzymes (calpains and cathepsins; Wiklund et al., 1997, 2010a; Farouk et al., 2007) and the small muscle fiber diameter (Taylor et al., 2002). Why the proteolytic enzymes are so active in venison is not completely clear; however, previous studies indicate that it could be related to the strong seasonality of deer growth, which is regulated by photoperiod (daylength; Suttie and Webster, 1998). This means that dramatic changes in body weight and condition are part of the normal annual growth cycle for deer and that the proteolytic enzymes have important functions in the living animal (Pösö et al., 2001; Wiklund et al., 2010a).

Cold-shortening and electrical stimulation. When carcasses are cooled too quickly, the muscles tend to contract substantially, which is called "cold-shortening" (Savell et al., 2005). The resulting meat is very tough and will not age or tenderize with time. To prevent cold-shortening, carcasses from domestic animals are frequently electrically stimulated. During electrical stimulation, a current is conducted through the carcass for a short time (0.5 to 1 minute), causing the muscles to contract rapidly, exhausting their energy (glycogen) stores, and thereby accelerating rigor attainment; consequently, the natural enzymatic tenderizing process in the resulting meat is enhanced. Electrical stimulation is used at commercial slaughter abattoirs in many countries for species like cattle, sheep, and goats. In New Zealand, electrical stimulation of deer carcasses is part of the normal slaughter routine at the deer abattoirs. However, the reindeer slaughter plants in Fennoscandia do not use electrical stimulation for reindeer carcasses.

The majority of reindeer in Alaska are slaughtered through a state-regulated field slaughter system. Field-slaughtered reindeer meat can be marketed locally provided animals are slaughtered on snow when ambient temperature is below 0°C, carcasses are allowed to freeze in the field, and the meat is not thawed until in the hands of the consumer (Alaska Department of Environmental Conservation, 2003). As ambient air temperatures during field slaughtering are usually below -10°C, instant chilling and freezing of the carcasses inevitably occurs, and the risk of cold shortening is obvious in field-slaughtered reindeer (Figure 6). This risk could be minimized with electrical stimulation immediately post slaughter. Portable electrical stimulation equipment that can be connected to a generator or a battery is available and has been proven to function well in the harsh environment during the winter field slaughter of reindeer in the Seward Peninsula of Alaska (Wiklund et al., 2008b). The positive effect of electrical stimulation on meat tenderness was clearly demonstrated by consumers judging meat from field-slaughtered stimulated reindeer to be more tender than that from unstimulated animals (Wiklund et al., 2008b).

Carcass suspension. It is well known that the carcass-handling conditions during development of rigor mortis are very important in controlling meat tenderization. Carcass suspension techniques have been studied for beef and shown to affect the tenderness of different muscles (Lundesjö Ahnström, 2008). The most common method to hang a carcass is by the Achilles tendon, but the pelvic suspension technique is also used (where the carcass is hung by a hook through the pelvic bone). Pelvic suspension stretches different muscles on the carcass compared with Achilles tendon suspension. Generally, muscles stretched more during rigor development will result in more tender meat. Most of the valuable cuts from the carcass (from the hind-quarter region) are more stretched by pelvic suspension than if the carcass was hung by the Achilles tendon, although this is not true for the tenderloin (*M. psoas major*). Pelvic suspension improved tenderness in several valuable venison cuts [striploin (*M. longissimus*), inside (*M. semimembranosus*), outside (*M. biceps femoris*), and knuckle (*M. quadriceps femoris*)] compared with Achilles tendon suspension for fallow deer, red deer, and reindeer (Wiklund et al., 2012; Hutchison et al., 2014;).

Water-holding capacity and color

Meat is composed of about 75% water, and the retention of this water throughout the supply chain is a measure of the eating and processing quality of meat. The ability of chilled meat to hold water is usually called water-holding capacity. Although tenderness is a key quality attribute of venison, the advanced level of proteolysis associated with this rapid tenderization makes it more susceptible to decreased water-holding capacity (Farouk et al., 2009), which is of major concern to meat industries in countries like New Zealand, Australia, and South America that export large volumes of chilled, vacuum-packaged meat cuts. Because venison is a very lean meat, the ability to retain the moisture during dry-heat cooking such as pan frying, grilling, and other dry cookery is of paramount importance to the eating quality of the meat. Failure to retain this water can ruin a tender venison cut due to lack of juiciness.

Consumers judge the acceptability of meat color by how bright red the meat looks on display. The browning of meat, which determines the color display life, is due to the reaction in which red oxymyoglobin is oxidized to brownish metmyoglobin. Venison contains a greater concentration of myoglobin (Young and West, 2001) and pro-oxidants such as iron and copper (Drew and Seman, 1987; Stevenson-Barry et al., 1999) than beef. These facts probably explain why venison has a darker red color and a rapid color deterioration, (i.e., short color display life, relative to beef; Farouk et al., 2007).

The quality differences between beef and venison strongly suggest species-specific tailoring of process inputs is required by meat processors if the water-holding capacity and color of these meats are to be optimized (Farouk et al., 2009).

Meat composition and flavor

Natural or managed pastures (grasses, herbs, and bushes) contain greater proportions of polyunsaturated fatty acids (PUFA) of total fatty acids and are also rich in different antioxidants. Grain-based feeds have more saturated fatty acids (SFA), and antioxidants like vitamin E are often added to commercial feed mixtures. When animals are grazing pasture or if they are fed grains, the fatty acid composition in their muscles will change towards the composition of their feed (Wood et al., 2008). Fatty acid profiles in red deer and reindeer venison related to feed type have been thoroughly investigated and linked to venison flavor. Deer/reindeer grazing pasture produced PUFA-rich venison with more "grassy," "gamey," and "wild" flavors while the grain fed animals yielded meat with significantly less PUFA and a "mild" and "beef-like" flavor (Wiklund et al., 2003a,b). These flavor differences were demonstrated using both trained sensory panels and consumer tests. Grain-based reindeer feed mixtures formulated to contain linseed cake (Sampels et al., 2006) and fish meal (Finstad et al., 2007) had increased PUFA content, and the fat composition of the venison from reindeer fed these diets was found to be very similar to that of reindeer venison from grazing animals.

The image of venison as a natural product with inherent health-promoting characteristics, produced ethically and humanely in a wholesome and pristine environment, is important for the success of the venison industries. As the industries expand and integrate more intensive feeding strategies, care must be taken that this image is not compromised.

Conclusions

The red deer and reindeer industries in New Zealand, Fennoscandia, and Alaska are producing some of the most prestigious sources of animal proteins, which attract premiums in high-value markets around the globe. Venison earned this prestige due to its naturalness, provenance, and inherent leanness and tenderness, all qualities that endear it to some of the most discerning consumers of meat. For the venison industries to maintain this image and to continue to prosper, processing practices in the abattoirs and during field slaughter must be tailored to the fast tenderizing and browning tendencies of venison to optimize its eating and aesthetic qualities.

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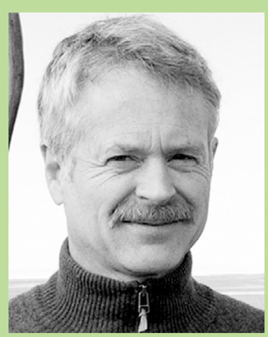

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